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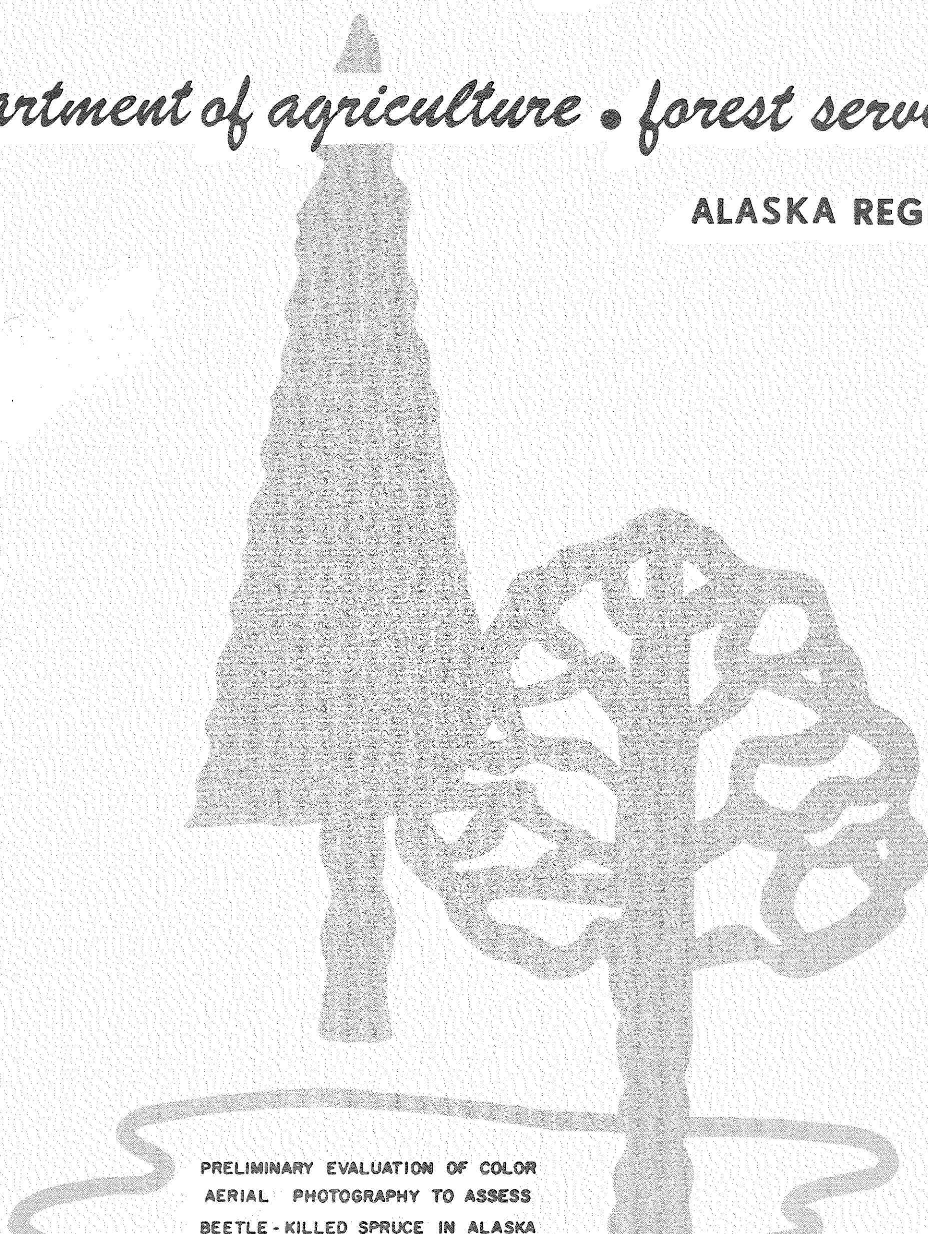

PRELIMINARY EVALUATION OF COLOR AERIAL PHOTOGRAPHY TO ASSESS BEETLE-KILLED SPRUCE IN ALASKA

Preliminary Evaluation of Color Aerial Photography to Assess Beetle-Killed Spruce in Alaska

by

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INTRODUCTION

Periodic outbreaks of the spruce beetle, Dendroctonus rufipennis Kirby, have resulted in widespread white spruce, Picea glauca (Moench) Voss, mortality in southcentral Alaska (Baker and Kemperman 1974). Over half a million acres of white spruce have suffered heavy mortality in the Cook Inlet basin since 1958 (Rush and Baker 1975). Because of the large acreages involved, it is generally impractical to estimate spruce mortality using conventional ground methods.

The use of color aerial photography for estimating insect-caused tree damage and mortality is well established. Large-scale, small format photographs have been successfully used to evaluate mountain pine beetle infestations in southeastern Idaho (Klein 1973, 1975, 1976) and to estimate white fir mortality caused by the Douglas-fir tussock moth in California (Wert and Wickman 1970). Attempts have also been made to use this method to evaluate Englemann spruce mortality in Colorado (Wear, et al. 1966). However, this application involved fading spruce crowns which were difficult to identify with a sufficient degree of precision to be useful. More recently, Lessard and Wilson (1977) successfully employed 70-mm aerial infrared photography to assess "old" beetle-caused spruce mortality in Arizona.

OBJECTIVES

The principal objective was to test the feasibility of using aerial photography and double sampling to assess white spruce mortality in Alaska. This was applied to past spruce beetle infestations so that dead trees would appear gray rather than the varied colors typical of fading crowns. A secondary objective was to determine how well associated live trees could be counted on aerial photographs.

METHODS

This evaluation was based on another ongoing impact evaluation to take advantage of considerable ground truth already available. 1/ Tree species, dbh, crown coloration, insect infestation and live and dead tree counts were recorded on 18 rectangular one-fifth acre plots during July 1976. The plots were located on the west side of the Kenai Peninsula (Figure 1).

1/ Data were extracted from a separate Forest Service study being jointly conducted by Forest Insect and Disease Management, Alaska Region; Pacific Northwest Forest and Range Experiment Station; and Rocky Mountain Forest and Range Experiment Station.

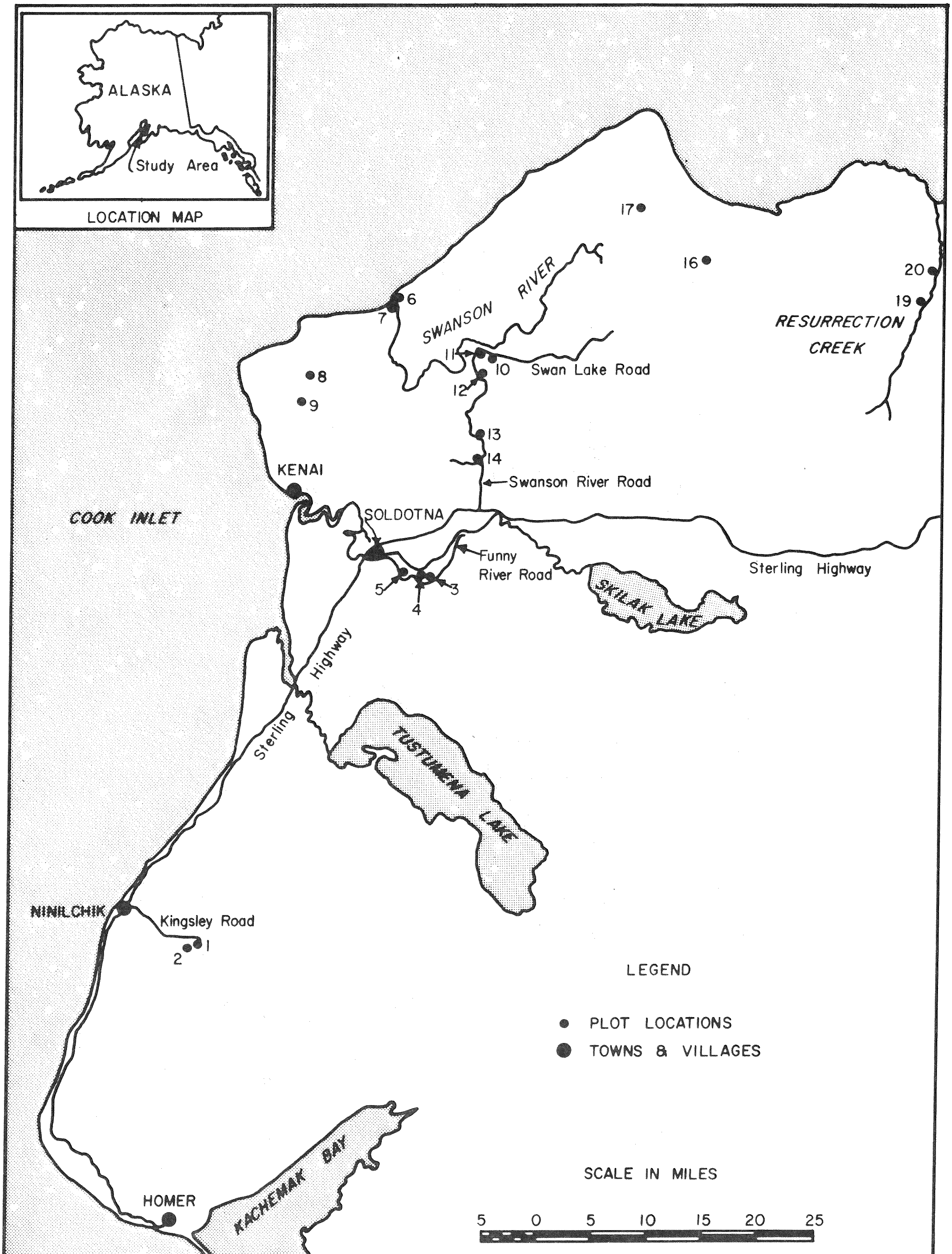


Figure 1. Plot locations on the Kenai Peninsula.

The one-chain by two-chain plots were marked on two corners with 36-inch wide muslin panels so that plot boundaries could later be seen on aerial photographs (Figure 2). The panels were stapled to four wooden stakes driven nearly flush with the ground. Placement of the cloth panels was dependent upon the presence of tree canopy cover over the plot corners. The two corners thought to be most visible from the air were marked.

Figure 2. Muslin panels were used to mark two corners of each 1/5-acre plot.

Aerial photography was obtained using a Hasselblad 500 EL/M with an 80-mm f/2.8 lens and a 70-exposure magazine (Figure 3). Kodak Ektachrome MS Aerographic (2448) film was exposed at an ASA of 150. Preliminary tests revealed that, late in the summer, photography taken on overcast days (Figure 4) was preferable to that taken on clear days because low sun angle created long dark shadows even when photographs were taken during the optimum time of the day. Overcast sky conditions were, therefore, sought whenever possible.

The photographs were taken during August and September, 1976, from a Turbo-Beaver flying at 2100 feet above ground level at a ground speed of 80 mph. Flight lines were flown on a north-south axis to help determine the orientation of plot markers on the photos. Stereo pairs or triplets were exposed at an approximate interval of three seconds.

After processing, the color positives were placed in glass sandwich mounts. The stereo pair giving the best coverage was then selected for each plot. Exposure, plot placement, shadows and marker visibility were considered. Each stereo pair was then covered with an acetate template, finely scribed to show the plot boundaries. It was in this step that the distances between markers could be measured and the template defining the exact plot boundaries could be made in spite of slight differences in flight altitude from plot to plot.

The 18 photo-pairs with templates attached were then interpreted by seven people using a pocket stereoscope on a standard light table. The seven interpreters had varying degrees of interpretive experience. Each person counted the number of dead spruce, live spruce and live hardwoods.

Aerial and ground tree counts were compared using regression analysis. Regression coefficients were calculated for each interpreter by tree group: dead, live and hardwoods.

RESULTS

A summary of the aerial photographic data appears in Appendix Table 1. Photo scale on the 18 plots ranged from 1:7540 to 1:8800, with a mean of 1:8080. This was very close to the intended 1:8000. Generally plot markers were sufficiently visible to define plot boundaries. Markers showed up best in photographs taken under overcast conditions.

Regression analysis yielded varied results (Appendix Tables 2 and 3). Correlation coefficients (r^2) for the seven interpreters ranged from 0.40 to 0.82. Analysis of covariance revealed no significant differences ($P<0.05$) between interpreters (Figures 5, 6 and 7). Therefore all data were pooled and single regression equations developed for dead spruce counts, live spruce counts and hardwood counts. Results are summarized in Table 1.

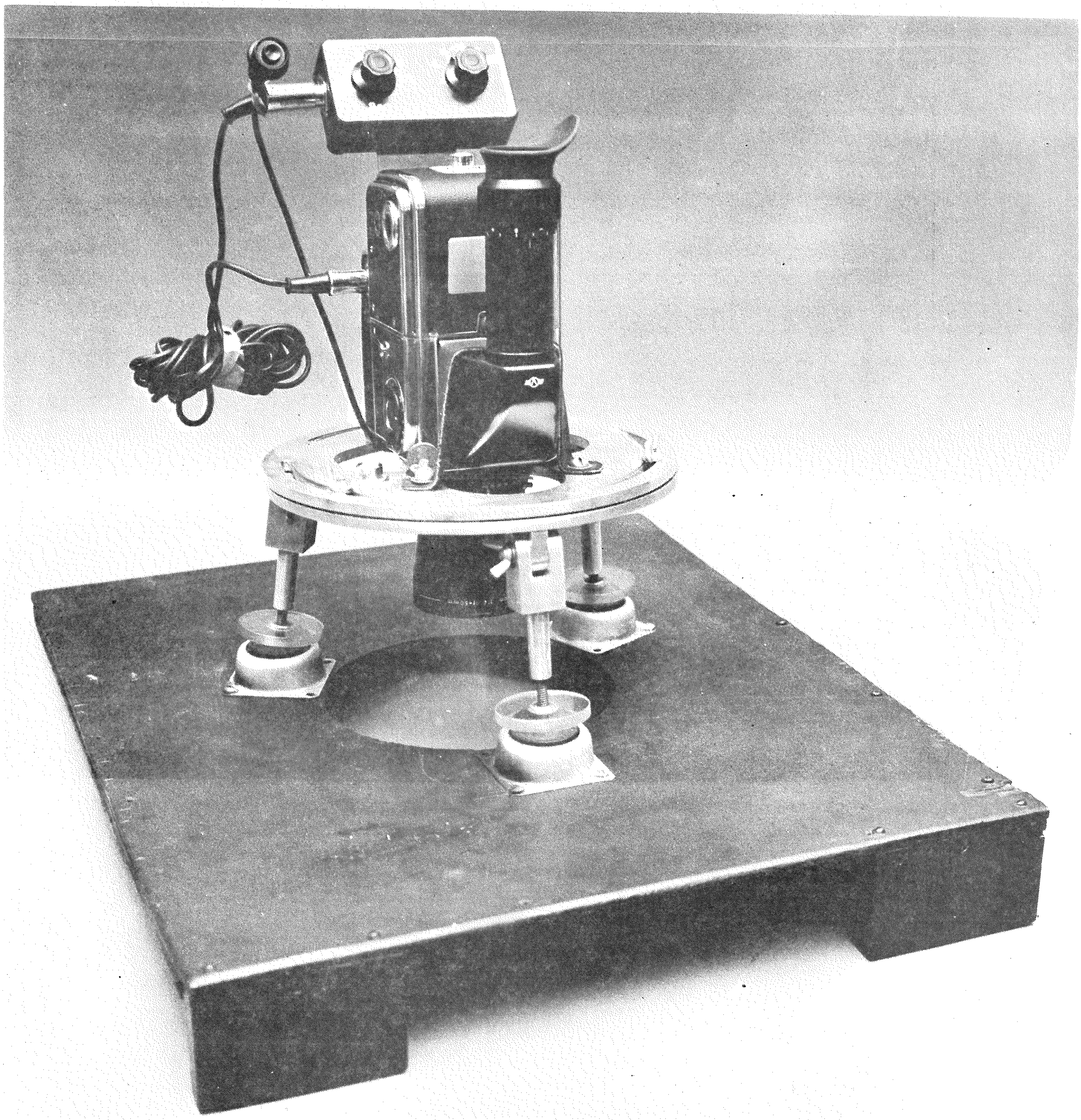
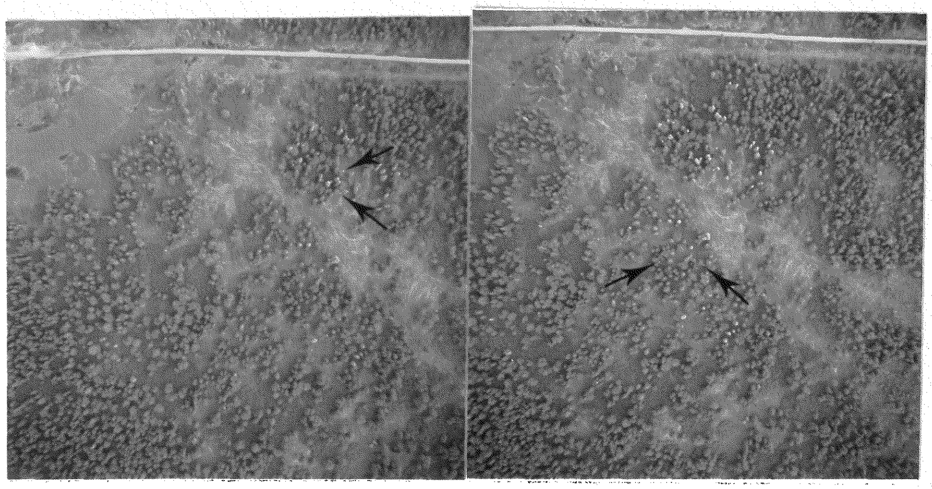


Figure 3. Camera, intervalometer and mount system used to photograph spruce mortality (a 50-mm lens is featured in this illustration).



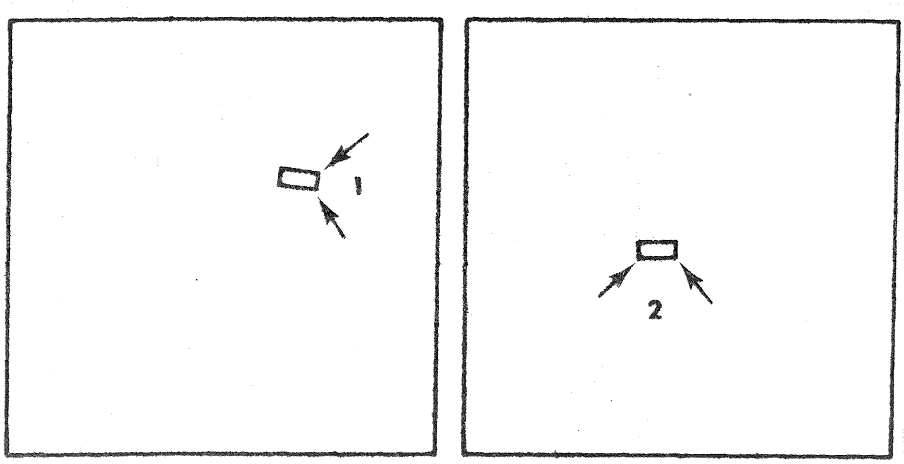


Figure 4. Stereogram showing plots 1 and 2, photographed under overcast condition. Note white corner markers. Plot 1 has 40 live spruce, 6 dead spruce and 9 hardwoods. Plot 2 has 20 live spruce, no dead spruce and 14 hardwoods (Note: Actual interpretation was made on original positive transparencies).

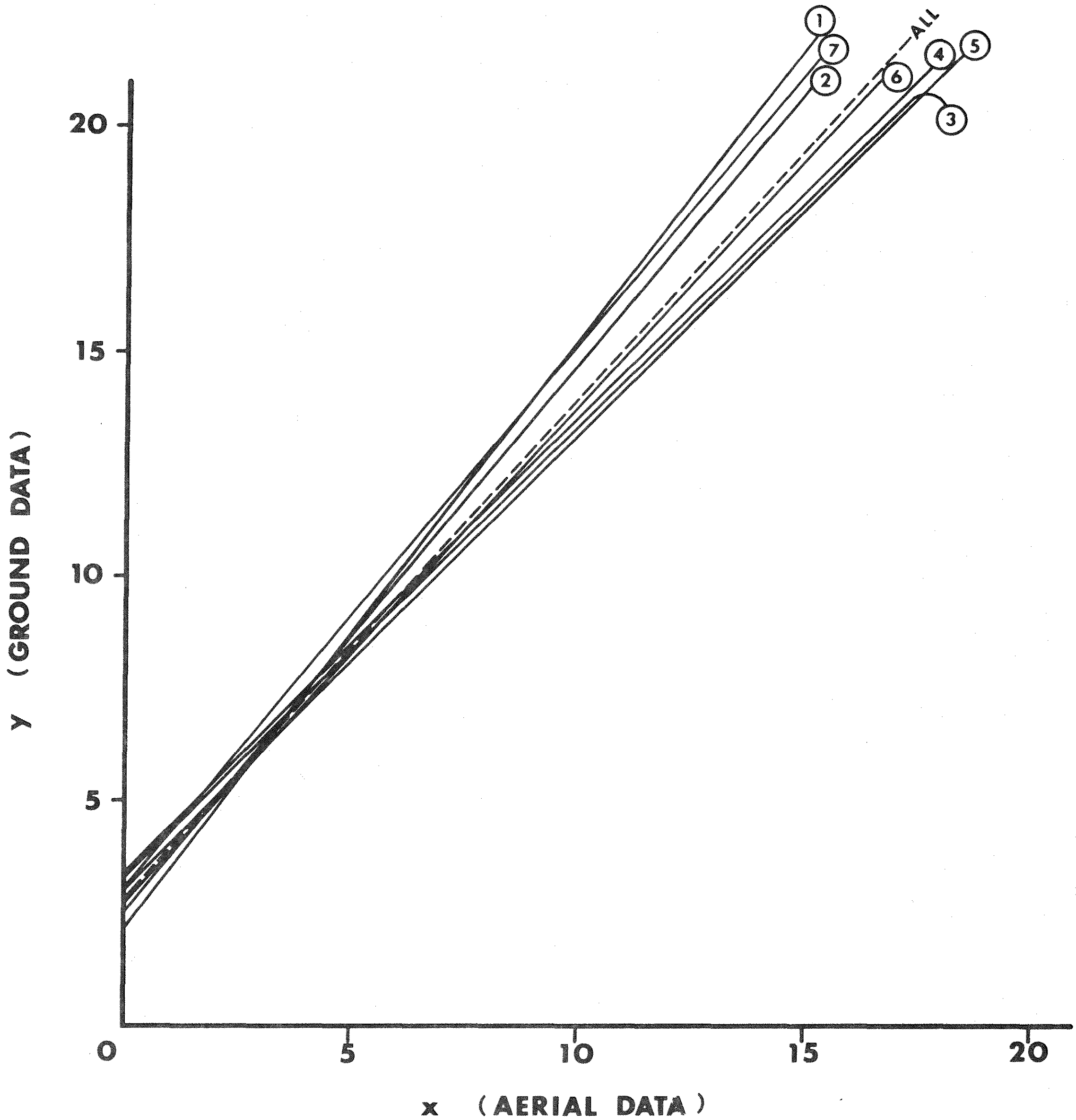


Figure 5. Linear relationship between actual number of dead spruce on one-fifth acre plot (ground data) and the number estimated from aerial photographs (aerial data), for each of 7 interpreters.

Interpreter	Equation	Sample size
1	$y = 2.3 + 1.3x$	18
2	$y = 2.7 + 1.2x$	18
3	$y = 3.3 + 1.0x$	18
4	$y = 3.5 + 1.0x$	18
5	$y = 3.1 + 1.0x$	18
6	$y = 2.8 + 1.1x$	18
7	$y = 3.1 + 1.2x$	18
Pooled	$y = 3.0 + 1.1x$	126

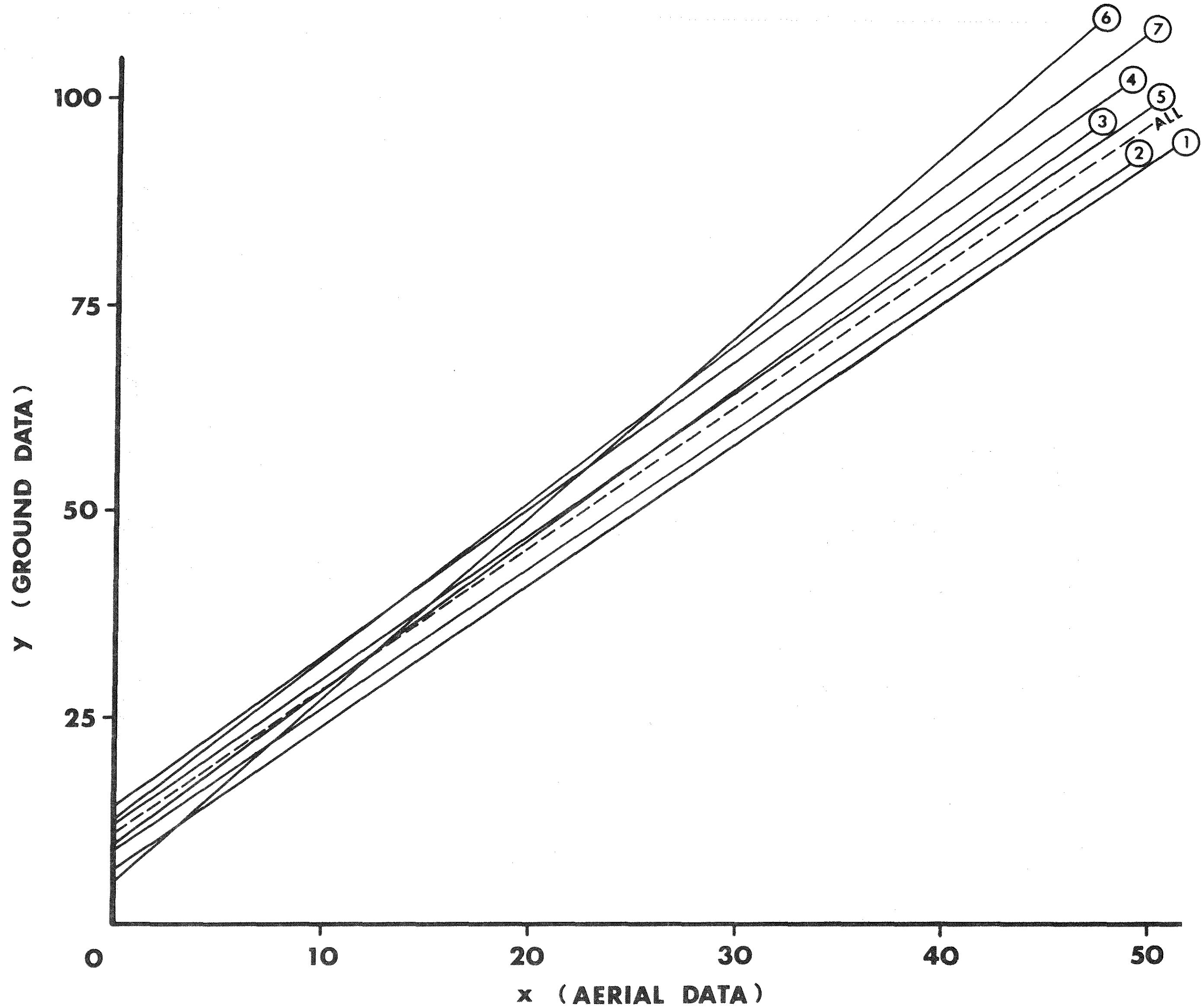


Figure 6. Linear relationship between actual number of live spruce on one-fifth acre plots (ground data) and the number estimated from aerial photographs (aerial data), for each of 7 interpreters.

Interpreter	Equation	Sample size
1	y = 7.3 + 1.7x	18
2	y = 9.4 + 1.7x	18
3	y = 9.9 + 1.7x	18
4	y = 14.5 + 1.8x	18
5	y = 12.5 + 1.6x	18
6	y = 5.7 + 2.2x	18
7	y = 13.3 + 1.9x	18
Pooled	y = 11.5 + 1.7x	126

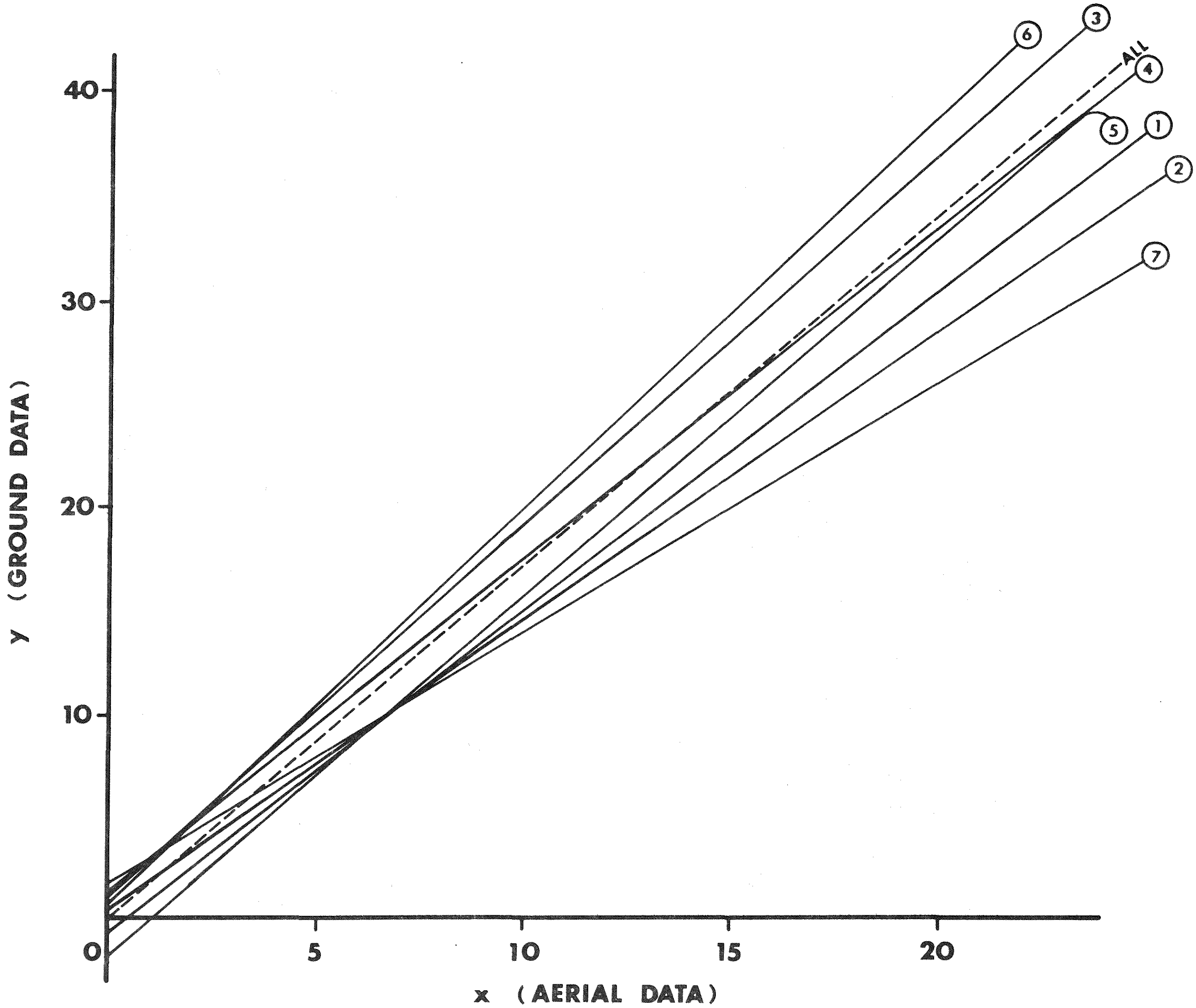


Figure 7. Linear relationship between actual number of hardwoods on one-fifth acres plots (ground data) and the number estimated from aerial photographs (aerial data), for each of 7 interpreters.

Interpreter	Equation	Sample size
1	$y = 0.3 + 1.5x$	18
2	$y = 0.4 + 1.4x$	18
3	$y = 0.9 + 1.8x$	18
4	$y = 1.5 + 1.6x$	18
5	$y = 0.8 + 1.6x$	18
6	$y = 1.7 + 1.9x$	18
7	$y = 1.9 + 1.2x$	18
Pooled	$y = 0.0 + 1.7x$	126

Table 1. Simple linear regression for estimating actual number of trees of various types (y) from counts made on aerial photographs (x).

Tree type	Regression equation	Correlation coefficient (r^2)
Dead spruce	$y = 3.0 + 1.1x$	0.464
Live spruce	$y = 11.5 + 1.7x$	0.738
Hardwoods	$y = 1.66x$	0.637

DISCUSSION and CONCLUSIONS

Questions regarding scale control, format size and operational feasibility have been answered by this evaluation. Although there was some variation in photographic scale, the mean of the photo samples was sufficiently close to the desired scale. Small-format 70-mm color positive transparencies at 1:8000 scale appear to contain sufficient detail to estimate numbers of trees. Detail in the photography and consistency of the interpreters (Figures 5, 6 and 7) show promise for application in spruce mortality surveys. Usefulness of photographs taken under overcast conditions provides needed flexibility in scheduling aerial tree mortality assessments. Photographic season and day length are extended considerably, a welcome relief for survey crews working at northern latitudes.

Although the r^2 values are not high, they do reveal that a significant relationship exists between actual counts and estimates made using aerial photographs. Stand composition and light conditions seem to be the two most important factors affecting the photo estimates.

Long shadows on photographs taken with low sun angle tend to mask useful information. Unfortunately, photography taken under overcast conditions was not available for all plots. The same difficulty in achieving uniform light conditions can also be confronted during operational surveys.

We did not have control over placement of the photo plots in this study as plots established for another study with a different purpose were used. This resulted in sampling stands that differed considerably in tree size, density and species composition as well as incidence of beetle-killed spruce. Sampling of heterogeneous stands with high variances is probably the factor most responsible for the lower correlation coefficients. Although such heterogeneous stand conditions could be encountered in an operational survey, it is unlikely that conditions would be as extreme as in this trial. Results should be considerably more accurate.

We are encouraged by these preliminary results and feel that similar methods applied over a more homogeneous area under more uniform light conditions would provide good estimates of beetle-killed spruce.

ACKNOWLEDGEMENTS

We appreciate the direct and indirect contributions to this study by other Forest Service personnel. Roy Beckwith (Corvallis, Oregon) initiated the original spruce beetle impact study from which the ground data were drawn. John Schmid (Fort Collins, Colorado) participated in collection of the ground data. Kay Eberth (Anchorage), Larry Yarger (Juneau), Mel Mehl (Juneau) and Ken Winterberger (Juneau) helped interpret the photography. Wilbur Farr (Juneau) counseled on data analysis.

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A P P E N D I X

Appendix Table 1

Summary of photographic quality.

						Photo Image Plot Size in Inches			
Plot No.	Photo Nos.	Exposure	Markers Visible	Photo Angle 1/	Marker Axis	Short Length	Long Length	Diagonal Length	Photo Scale
1	1-24,25	Good	2	Slight	Short	.095	.190	.212	1:8340
2	1-24,25	Good	2	None	Long	.096	.191	.214	1:8250
3	1-36,37	Good	2	Slight	Diagonal	.096	.192	.216	1:8250
4	1-36,37	Good	2	Slight	Diagonal	.096	.192	.215	1:8250
5	3-15,16	Fair	1 & Part	None	Diagonal	.094	.188	.210	1:8430
6	1-10,11	Good	2	None	Diagonal	.093	.186	.208	1:8520
7	1-13,14	Good	2	None	Long	.098	.196	.219	1:8080
8	1-15,16	Good	1 & Part	Slight	Diagonal	.100	.200	.225	1:7920
9	1-19,20	Fair	2	None	Short	.098	.196	.219	1:8080
10	3-1,2	Good	1 & Part	None	Short	.100	.200	.225	1:7920
11	3-9,10	Good	1 & Part	None	Short	.105	.210	.235	1:7540
12	3-22,23	Fair	1 & Part	None	Diagonal	.099	.198	.221	1:8000
13	2-12,13	Good	2 Parts	None	Short	.105	.210	.235	1:7540
14	2-8,9	Fair	2	None	Diagonal	.100	.200	.225	1:7920

16	3-30,31	Good	1 & Part	None	Long	.097	.194	.217	1:8170
17	3-28,29	Fair	1 & Part	None	Diagonal	.096	.192	.215	1:8250
19	3-36,37	Good	2	None	Long	.090	.180	.201	1:8800
20	3-38,39	Good	1 & Part	None	Short	.105	.210	.235	1:7540
Mean	---	---	---		---	.098	.196	.219	1:8080

1/ Amount photograph deviates from vertical.

Appendix Table 2

Summary of regression statistics for the seven interpreters.

Statistic	Interpreters							
	1	2	3	4	5	6	7	All
Dead spruce								
n	18	18	18	18	18	18	18	126
a_o	2.298	2.712	3.266	3.471	3.144	2.770	3.095	3.011
a_1=b	1.268	1.203	1.028	0.969	1.030	1.128	1.190	1.103
r^2	0.542	0.533	0.447	0.401	0.431	0.495	0.436	0.464
Sy.x	3.683	3.719	4.048	4.212	4.104	3.865	4.087	3.786
s_o	1.519	1.464	1.565	1.635	1.632	1.546	1.631	0.566
s_1	0.292	0.282	0.286	0.296	0.296	0.285	0.339	0.107
Live spruce								
n	18	18	18	18	18	18	18	126
a_o	7.300	9.435	9.900	14.485	12.533	5.651	13.259	11.530
a_1=b	1.722	1.725	1.715	1.784	1.637	2.169	1.893	1.731
r^2	0.783	0.825	0.812	0.743	0.748	0.656	0.759	0.738
Sy.x	10.971	9.850	10.216	11.939	11.824	13.814	11.567	11.459

s_o	5.188	4.360	4.499	4.864	5.040	7.258	4.821	1.900
s_1	0.227	0.199	0.207	0.263	0.238	0.393	0.267	0.093
Hardwoods								
n	18	18	18	18	18	18	18	126
a_o	-0.268	0.382	0.912	1.493	-0.781	0.710	1.852	1.059
$a_1=b$	1.520	1.421	1.793	1.553	1.597	1.898	1.241	1.479
r^2	0.645	0.581	0.775	0.652	0.767	0.729	0.576	0.637
Sy.x	4.533	4.920	3.608	4.485	3.668	3.962	4.951	4.356
s_o	2.149	2.307	0.358	1.846	1.691	1.670	2.062	0.708
s_1	0.282	0.302	0.059	0.284	0.220	0.290	0.266	0.100

Appendix Table 3

Summary of the raw data showing number of dead spruce (d), live spruce (l) and hardwoods (h).

Plot No.	Ground Truth			Interpreter estimates																				
				1			2			3			4			5			6			7		
	d	l	h	d	l	h	d	l	h	d	l	h	d	l	h	d	l	h	d	l	h	d	l	h
1	6	40	9	6	15	7	6	13	5	7	10	4	6	9	5	6	13	6	6	10	5	7	10	7
2	0	20	14	0	13	10	0	13	9	0	12	7	0	13	9	0	12	11	0	13	9	0	11	13
3	9	28	9	7	15	6	6	14	10	6	9	6	6	7	8	6	11	9	6	12	6	4	13	7
4	18	38	12	5	20	6	5	13	7	5	17	3	3	12	3	4	17	6	5	15	5	4	12	5
5	5	29	7	2	19	7	2	17	7	1	13	5	2	17	5	1	19	8	2	20	7	1	18	10
6	4	16	9	2	6	11	2	5	11	2	5	4	2	3	7	3	6	7	3	6	5	2	3	9
7	8	21	17	7	16	4	7	6	11	6	9	8	8	3	13	8	8	9	7	7	9	7	2	13
8	11	39	14	9	21	11	9	24	12	9	28	6	9	20	7	9	18	8	9	21	4	7	14	9
9	16	40	12	6	11	10	7	11	10	6	12	8	6	3	8	7	6	10	8	7	8	6	5	10
10	4	92	0	4	47	0	4	43	0	5	39	0	4	36	0	5	40	0	5	27	0	4	39	0
11	9	65	0	7	29	2	8	26	2	8	28	2	10	22	2	10	26	2	10	19	1	8	20	2
12	2	88	7	1	48	4	1	48	4	1	42	4	1	44	1	1	49	3	1	37	2	1	35	2
13	15	23	7	7	12	3	7	9	4	7	5	1	9	7	4	8	6	7	7	10	3	6	6	2
14	2	55	8	0	18	7	0	19	6	0	24	2	0	18	3	0	15	5	0	23	2	0	16	2
16	11	22	5	5	17	5	3	16	3	3	13	4	4	15	2	4	17	3	4	16	3	4	16	3

17	12	21	10	8	6	7	8	6	7	11	5	9	8	7	7	7	6	9	6	7	5	8	2	8
19	2	50	3	1	28	3	0	30	1	1	35	1	1	20	0	1	31	0	0	27	0	1	26	0
20	5	59	33	0	16	16	0	21	12	0	25	15	0	16	12	0	18	16	0	20	12	0	20	13